NET ZERO IN THE MAINSTREAM: NEW + EXISTING BUILDINGS

PEDCO High Performance Building Seminar

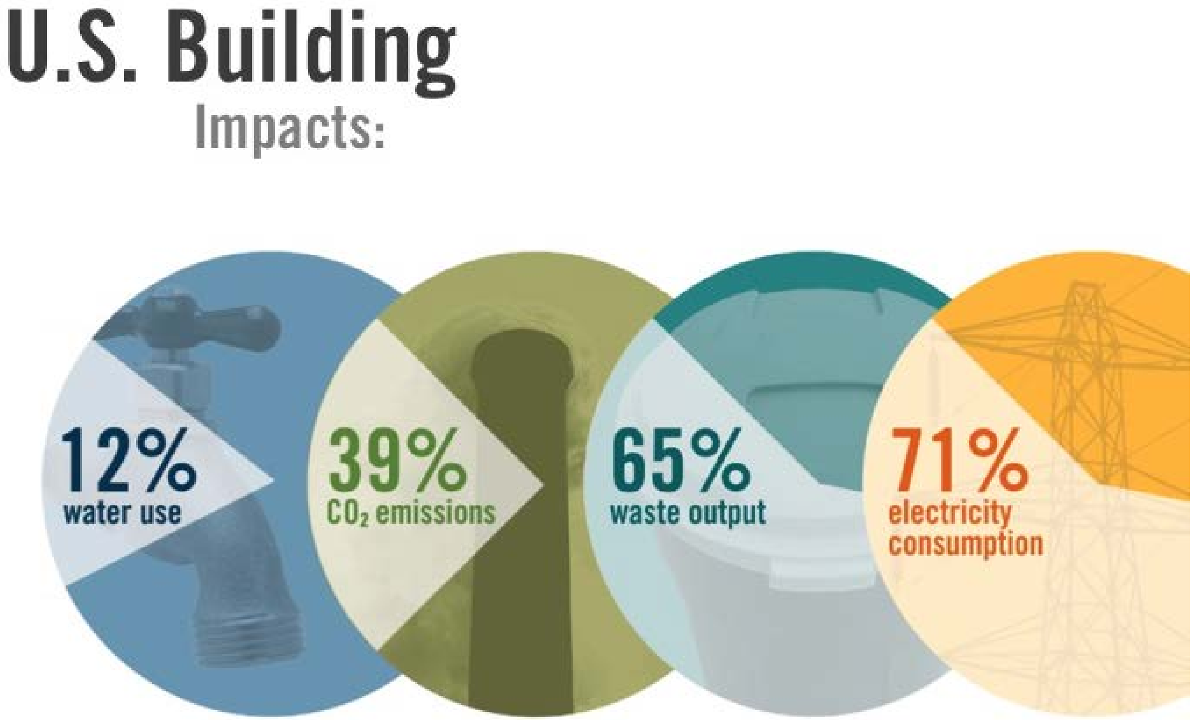
October 6, 2016

Northwestern | FACILITIES MANAGEMENT

Agenda

- Net Zero Energy Buildings (NZEB)
  - The Problem
  - NZEB: What? How? Who?
  - NZEB: Challenges + Drivers
- Northwestern University
  - About Northwestern University
  - Case Study: Simpson Quarry/ Chicago Campus Steam

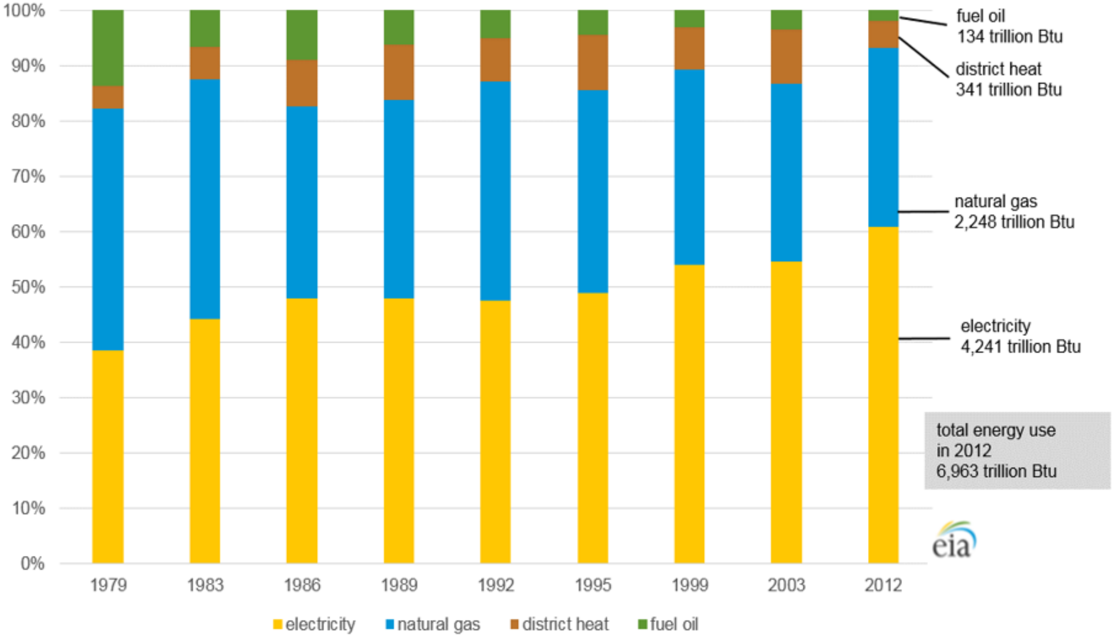
The Problem



*USGBC (2007), Building Impact on the Environment.

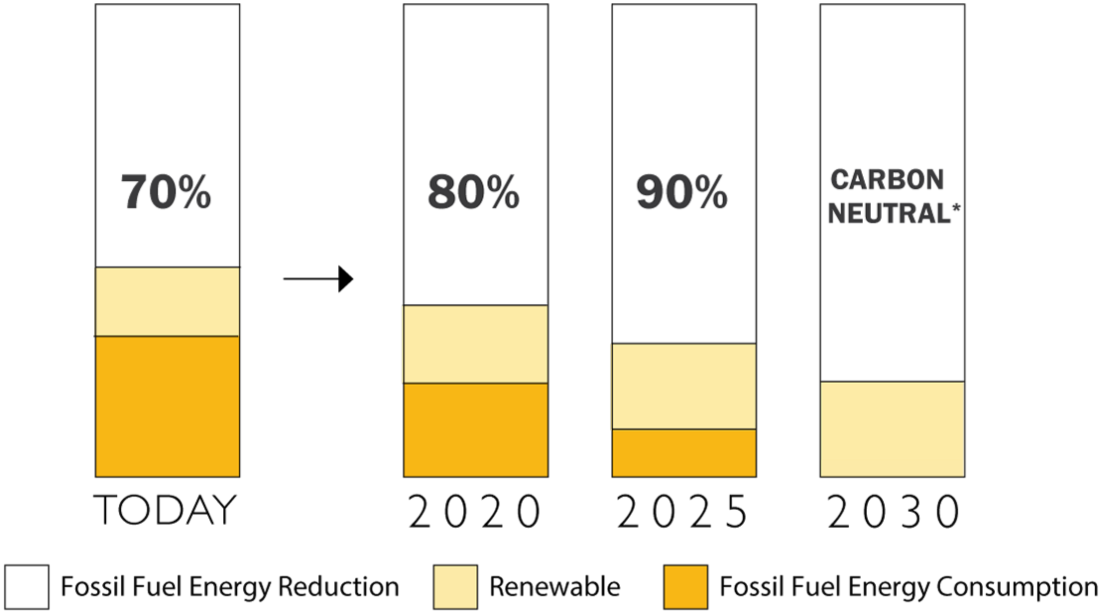
The Problem

Figure 2. Electricity now accounts for 61% of all energy consumed in commercial buildings



Source: U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey.

The Plan: The 2030 Challenge

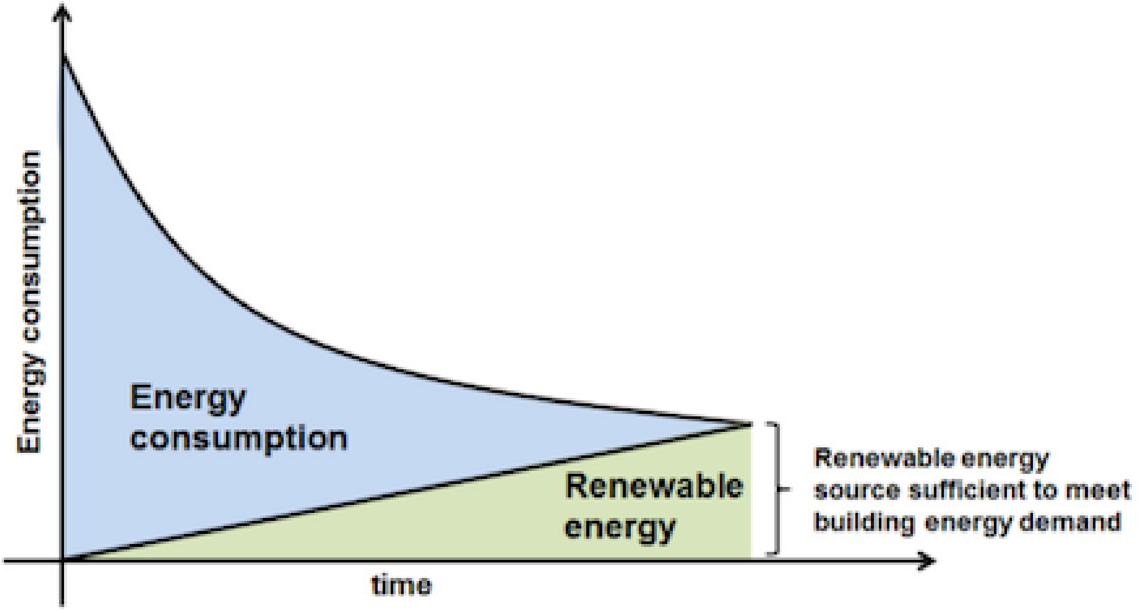


The 2030 Challenge

**Using no fossil fuel GHG-emitting energy to operate.*

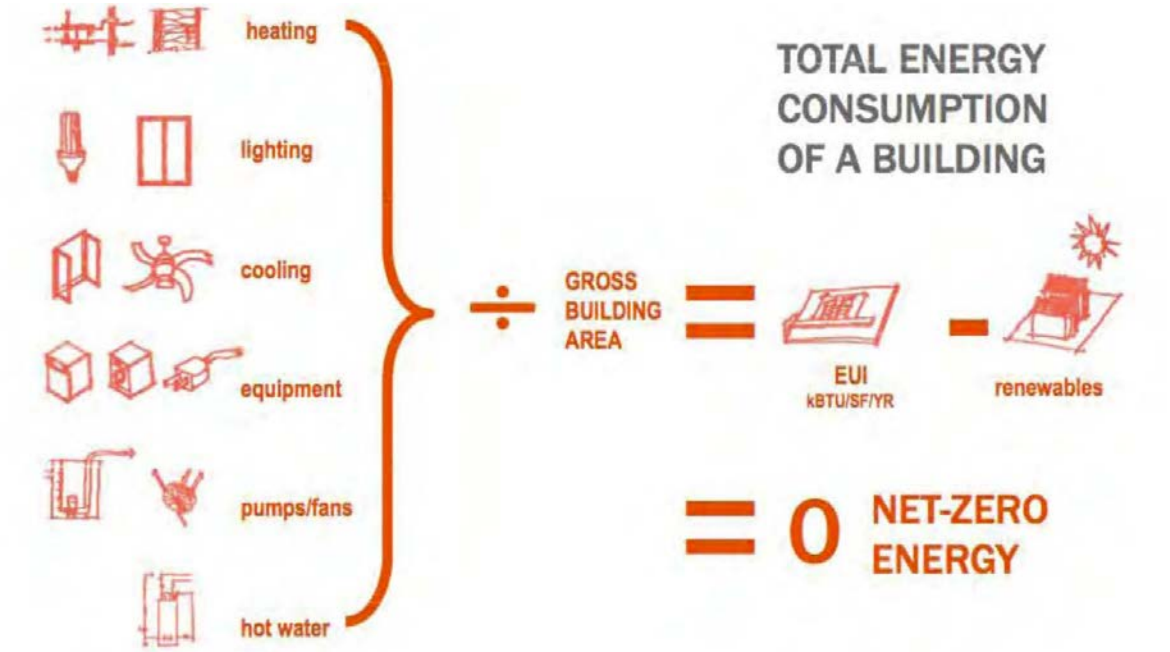
Net Zero Buildings: What?

Figure 1.1 Zero Energy Building Concept



(Source: Pike Research)

Net Zero Buildings: What?



Source: Massachusetts Chapter USGBC “Net Zero Energy Buildings”

Net Zero Buildings: How?

DESIGN STRATEGIES

The largest energy reductions can be achieved through design.

TECHNOLOGIES AND SYSTEMS

Including on-site renewable energy systems.

OFF-SITE RENEWABLE ENERGY

20% maximum.

Meeting the 2030 Challenge

Net Zero Buildings: How?

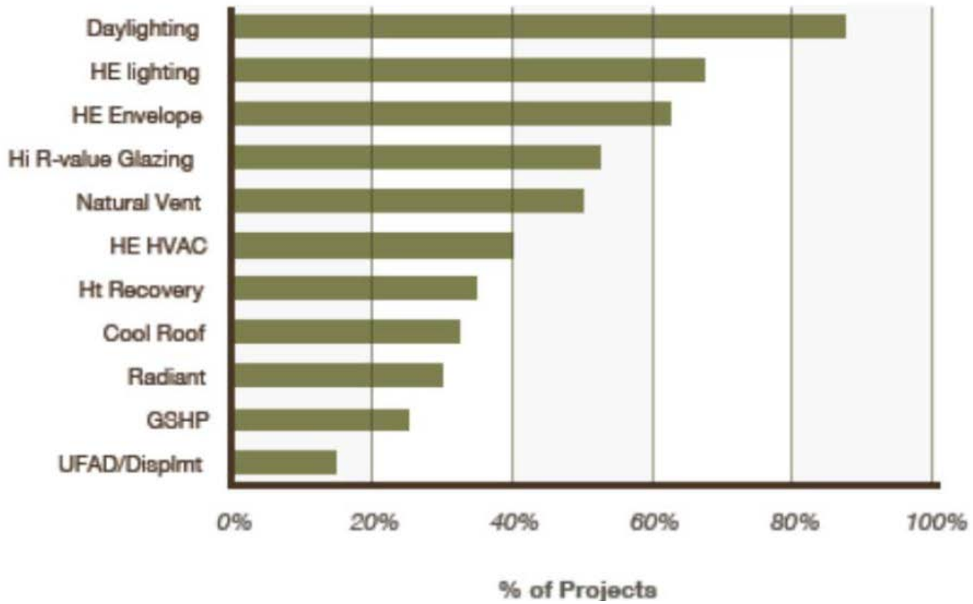
- The US National Renewable Energy Lab (NREL) published a Classification System:
  - NZEB:A -- A footprint renewables (On-site Renewables – Source)
  - NZEB:B -- A site renewables (On-site Renewables – Site)
  - NZEB:C -- An imported renewables – (Off-Site Renewables)
  - NZEB:D -- An off-site purchased renewables – (Renewable Credits)

Net Zero Buildings: How?

- Department of Energy: A Common Definition
  - Zero Energy Building is "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."

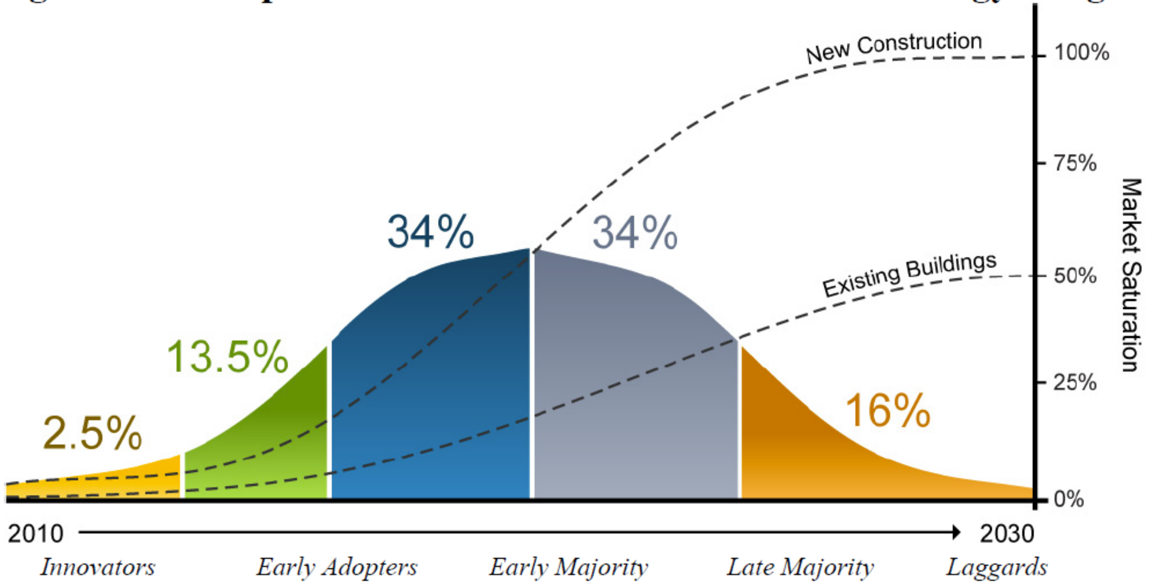
Net Zero Buildings: How?

Figure 3. Technologies Used in ZEB and Zero Energy-Capable Buildings



Net Zero Buildings: Who?

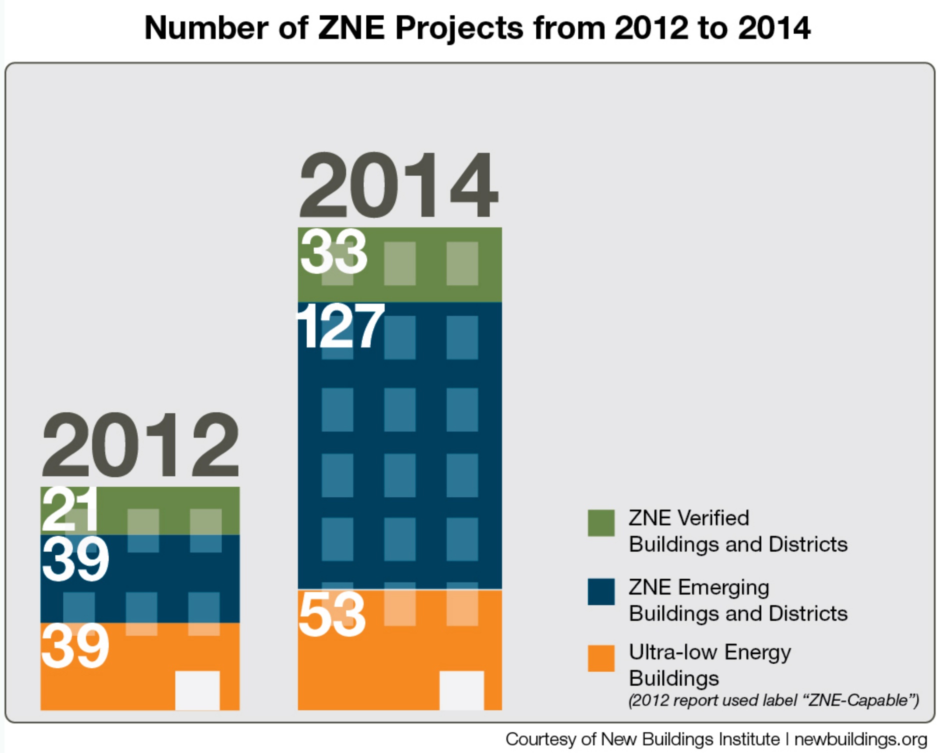
Figure 4. Conceptual Market Diffusion for Zero Net Energy Targets



Net Zero Buildings: Who?

<u>**5.6 Million**</u>

Commercial Buildings in US in 2012



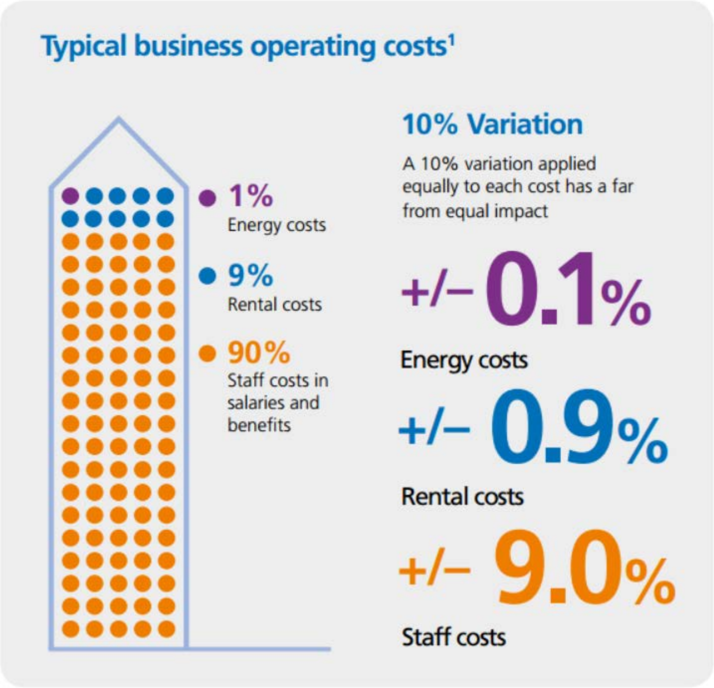
The Case for Net Zero (Green Building!)

- Risk Mitigation
  - Isolation from future energy price increases
  - Redundancy/ Emergency Preparedness
  - Improved Reliability
  - Future legislative restrictions, and carbon emission taxes
- Economics
  - Reduced total cost of ownership due to improved energy efficiency
  - Costs are minimized for new construction compared to a retrofit
  - Higher resale value due to demand for NZEB
- Increased Thermal Comfort!

Making the Case for Green Building

PEOPLE!

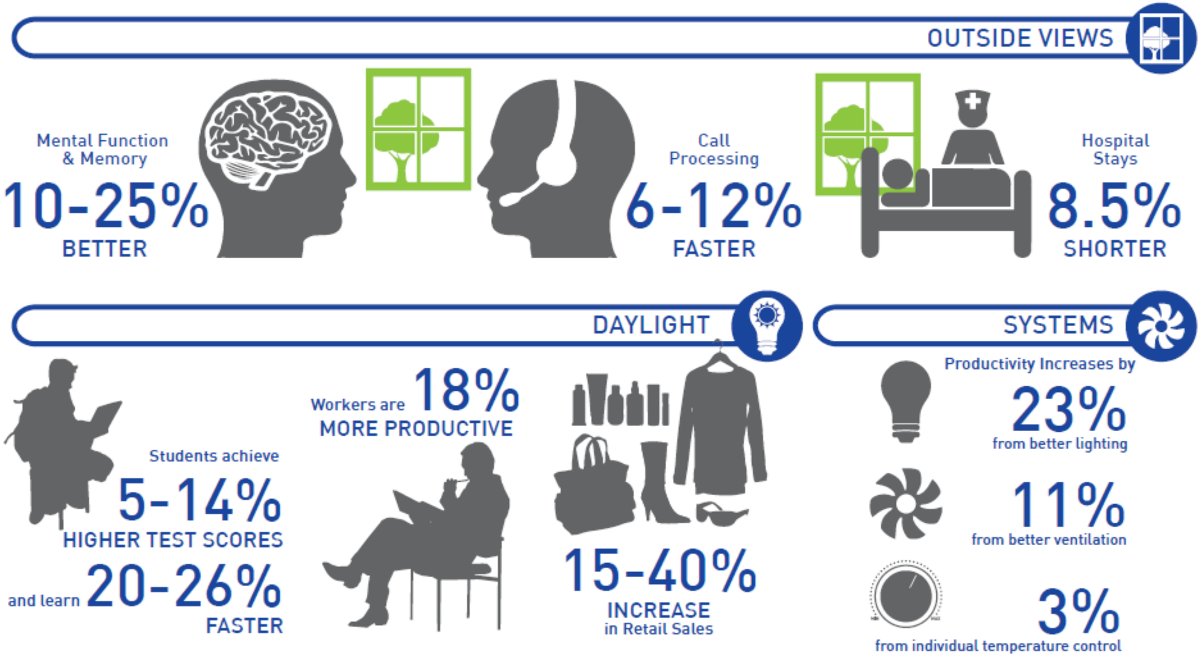
- The built environment has a significant impact on health, wellbeing and productivity
- In the U.S. absenteeism costs employers $2,074 per employee per year*
- Staff salaries and benefits account for 90% of a typical business' operating costs*



**Typical Business Operating Costs*

Source: The World Green Building Council. Health, Wellbeing and Productivity

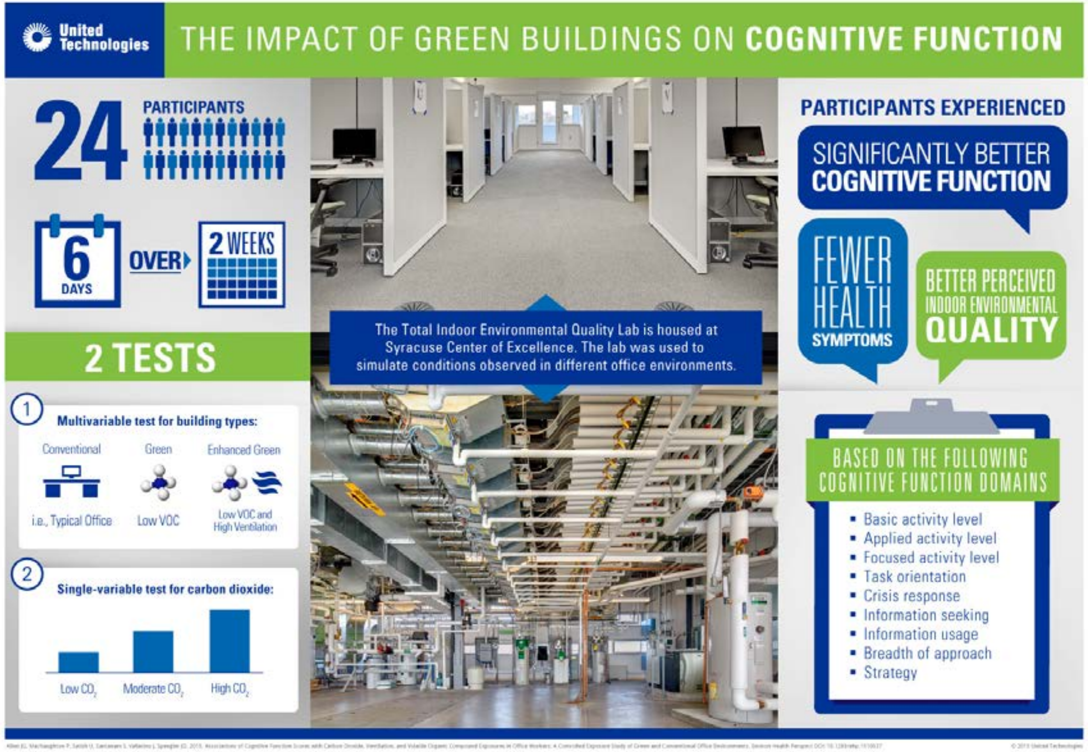
Making the Case for Green Building



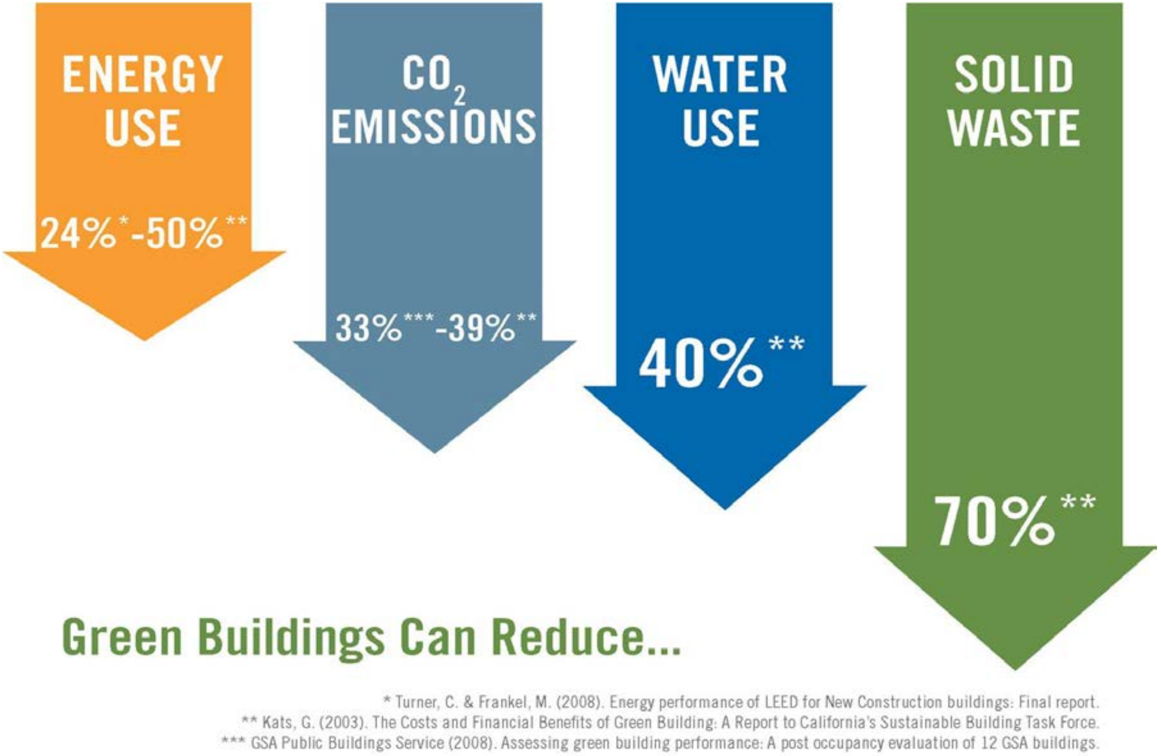
Net present value analysis of the operational cost and productivity and health benefits of LEED Certified buildings.

Source: The World Green Building Council. The Business for Green Building (Figure 11) 2013

Making the Case for Green Building



Making the Case for Green Building



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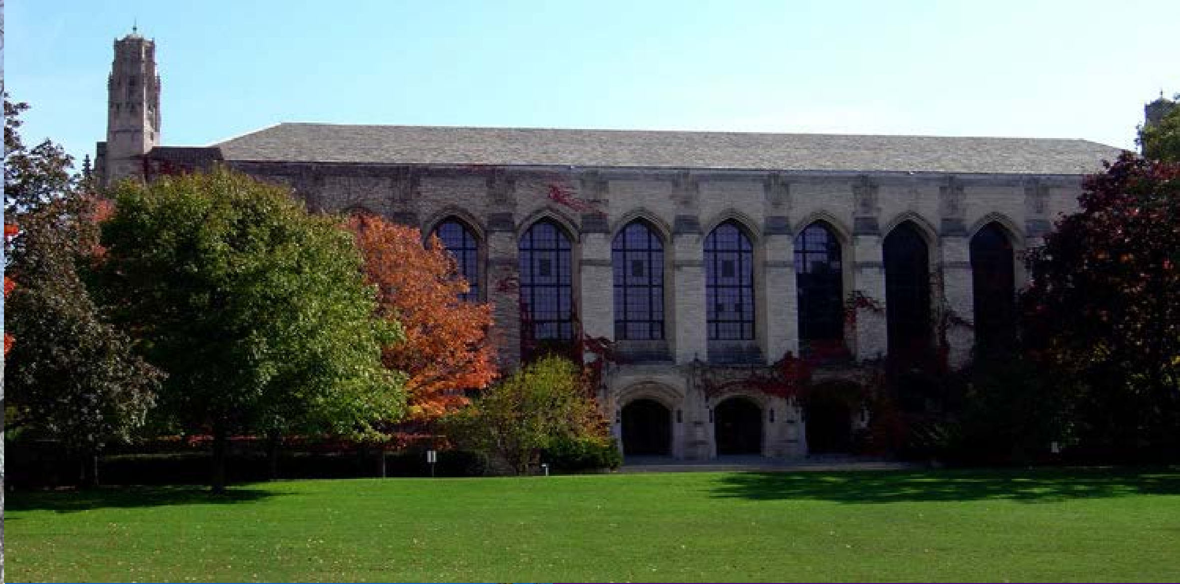
Harvard School of Public Health's Center for Health and the Global Environment, SUNY Upstate Medical, Syracuse University



NORTHWESTERN UNIVERSITY
QUAECUMQUE SUNT VERA
1851

NORTHWESTERN
UNIVERSITY

About Northwestern University

- 2 Main Campuses - Evanston and Chicago
- 12 Million Square Feet
- 265 Acres
- 198 Buildings
- 246,939,929 kWh of Electricity Annually
- 20,021,855 therms of Natural Gas Annually
- 50% REC’s
- 247 kBtu/SF

NU Sustainability Goals

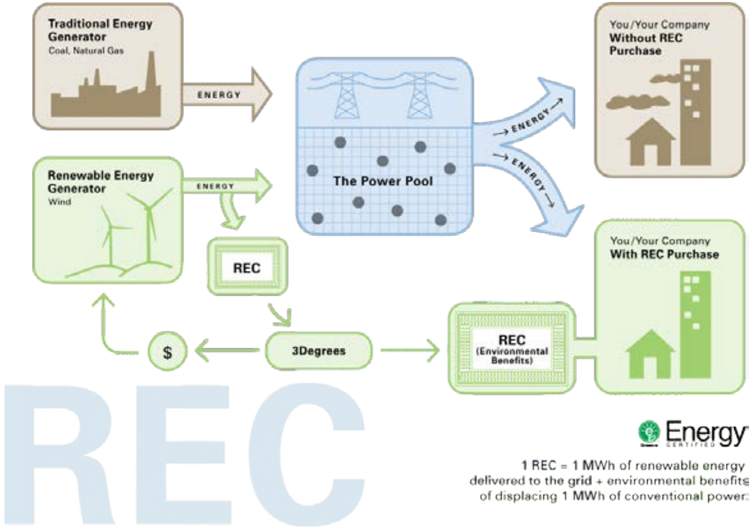
- At least a 2% energy reduction annually
- Short Term - 20% energy reduction per square foot from a 2010 baseline by 2020
- Long Term - 80% energy reduction by 2050 from the 2010 baseline.
- One Solar Array per year
- *Net Zero Strategy – Coming Soon…*

NU Sustainability Strategies

- ***Evaluate alternative technologies*** and fuels to decrease emissions from the central utility plant.
- Expand energy conservation through ***retro-commissioning*** systems across campus.
- Implement ***data center conservation strategies*** that reduce campus demand and energy use.
- Implement ***energy management program*** to improve energy efficiency in existing facilities through monitoring, identification and implementation of energy projects, and continuous commissioning.
- Implement ***Sub-metering Plan***
- Utilize ***energy management software to track and communicate energy use*** and progress toward goals at a campus, school, and facility level.
- Implement programs that ***educate students, faculty, and staff*** about energy use and engage them in energy conservation efforts.
- New construction/renovations to use ***50% less energy than required by current energy code***
- Achieve LEED BD+C certification of Gold or higher for all new buildings and renovations.
- Achieve LEED For Existing Buildings

REC's - 3 Degrees Approach

- US EPA ranks in Power Purchases:
  - NU 2nd in the Big Ten
  - 7th nationally
- 100% wind power from farms in Midwest & plains states
- Offsetting 122,550,467kWh/year (50% of total kWh)
- Annual impact equal to removing 18,193 Passenger vehicles driven in one year!



Green Building On Campus

GOLD CERTIFICATIONS

- Harris Hall
- NU Sailing Center
- Richard and Barbara Silverman Hall for Molecular Therapeutics & Diagnostics
- Rogers House
- Ryan Center for the Musical Arts
- Searle Hall
- Wieboldt Hall
- Segal Visitor's Center

SILVER CERTIFICATIONS

- 630 Emerson
- Ford Motor Company Engineering Design Center

IN PROGRESS

- Kellogg School of Management, New Building
- Kresge Centennial Hall

NORTHWESTERN UNIVERSITY

Louis A. Simpson & Kimberly K. Querrey Biomedical Research Center

Case Study: Getting Away from Campus Steam

Northwestern University

PERKINS + WILL

AEI Affiliated Engineers

LEARNIING OBJECTIVES

- Design influences in a dense urban area and the desire to maximize the project area **to reduce operational costs and focus on sustainability**.

- Understanding operational and energy cost savings differences between High Pressure Steam and Hot Water System generation and distribution.

- Methodology used to examine the **best approach to thermal heat generation systems** in new medical research buildings.

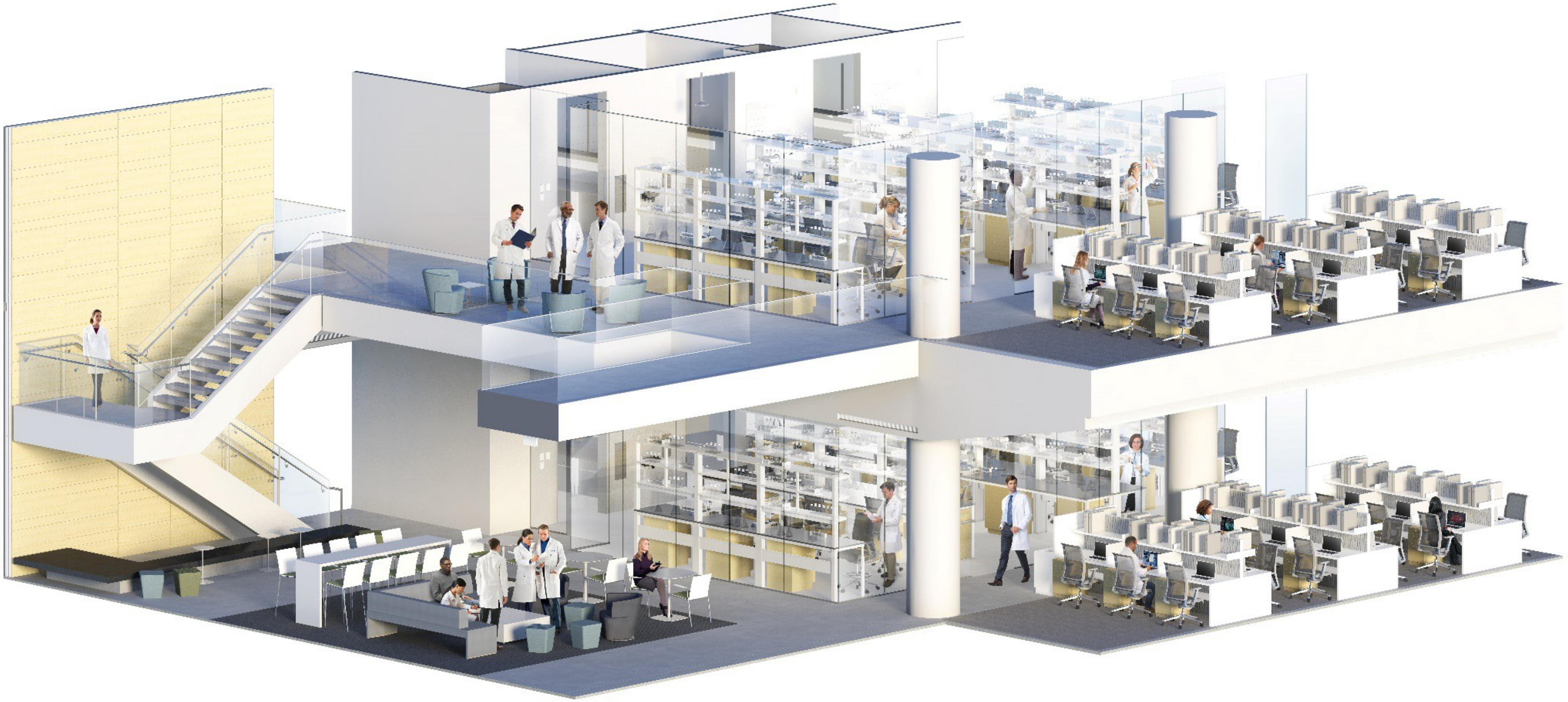
- Identifying **lab equipment alternatives** to utilizing high pressure steam sterilization equipment

AGENDA

- Introduction to Northwestern Louis A. Simpson & Kimberly K. Querrey Biomedical Research Center (NU SQBRC)

- The History of Campus Steam

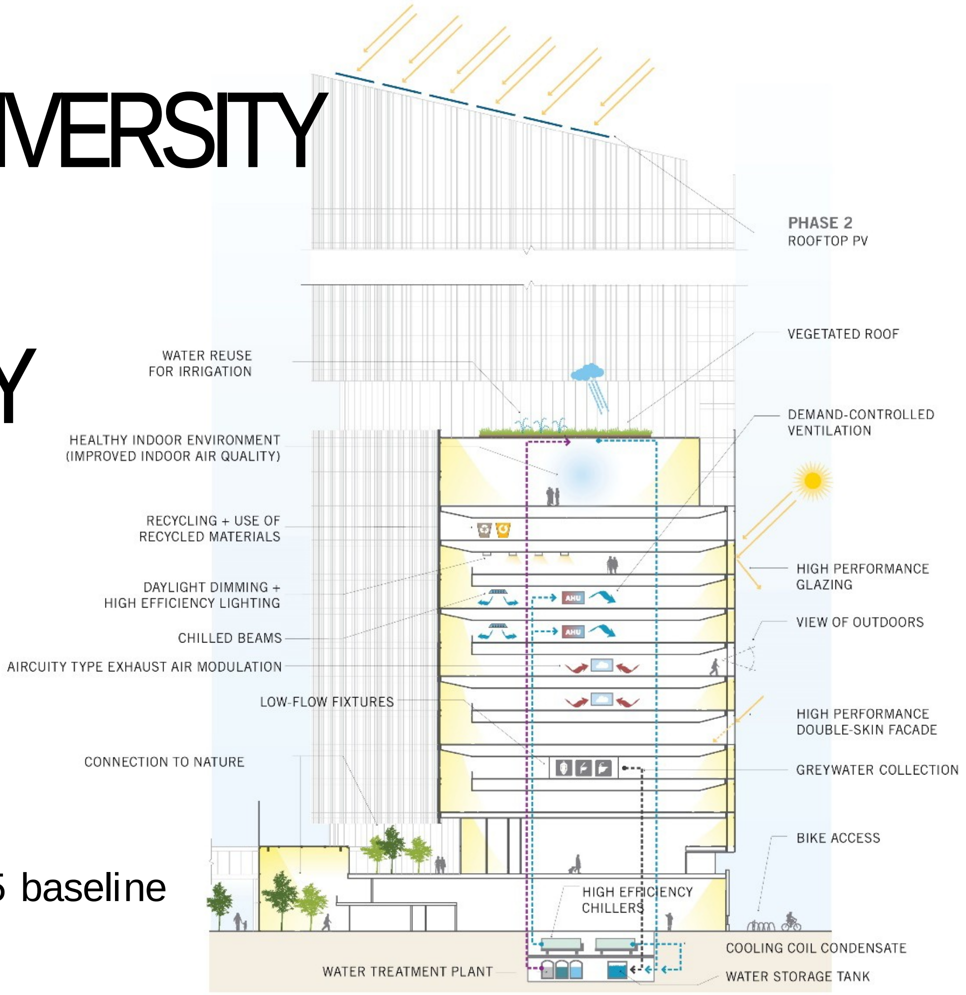
- SQBRC moves away from HPS



Typical Lab Floor

NORTHWESTERN UNIVERSITY STANDARDS MAXIMIZE EFFICIENCY

- LEED Gold Certification target for all new projects
- 20% Energy Efficiency target
- 25% reduction in water usage
- 30% in ghg emissions compared to 2005 baseline



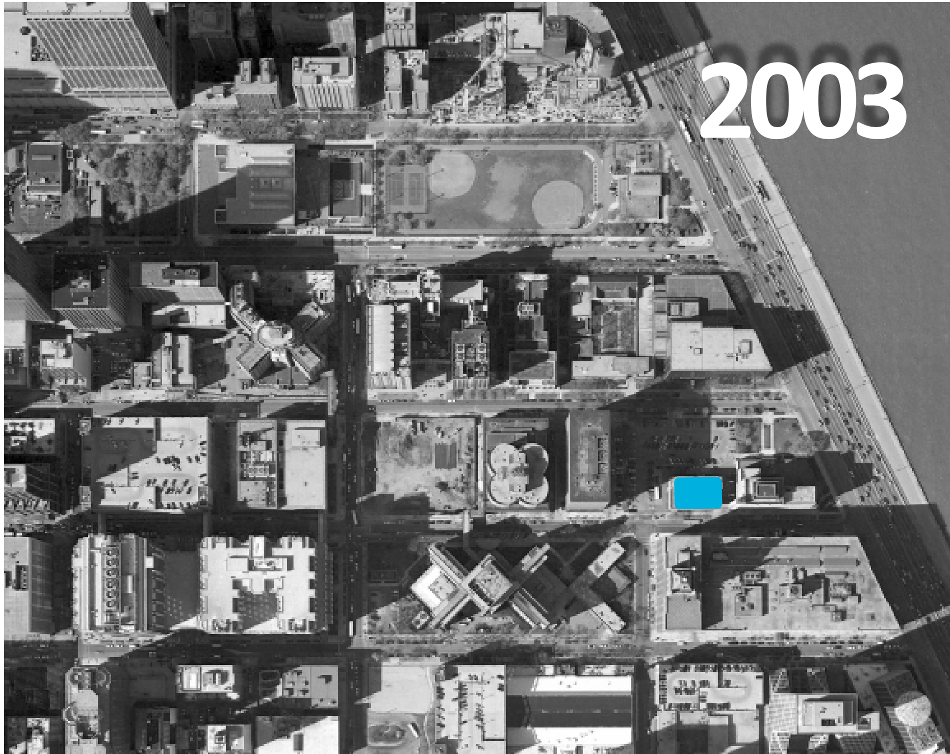
THE HISTORY OF CAMPUS STEAM

Aerial View of Northwestern University Campus in 1958 /

CHICAGO HISTORIC CAMPUS

- 20-Acre, 2M SF over 12 Buildings
- Pritzker School of Law
- Feinberg School of Medicine
- Medical Research
- Kellogg School of Management
- School of Professional Studies

HIGH PRESSURE STEAM UTILIZATION



HIGH PRESSURE STEAM PRODUCTION / DISTRIBUTION

- Constructed in 1958
- 4 boilers / 455,000 lbs./hr. production capability
- Original coal fired / converted to gas early 1980's
- Served Northwestern Memorial Campus and Northwestern Memorial Hospital

CAMPUS STEAM PLANT

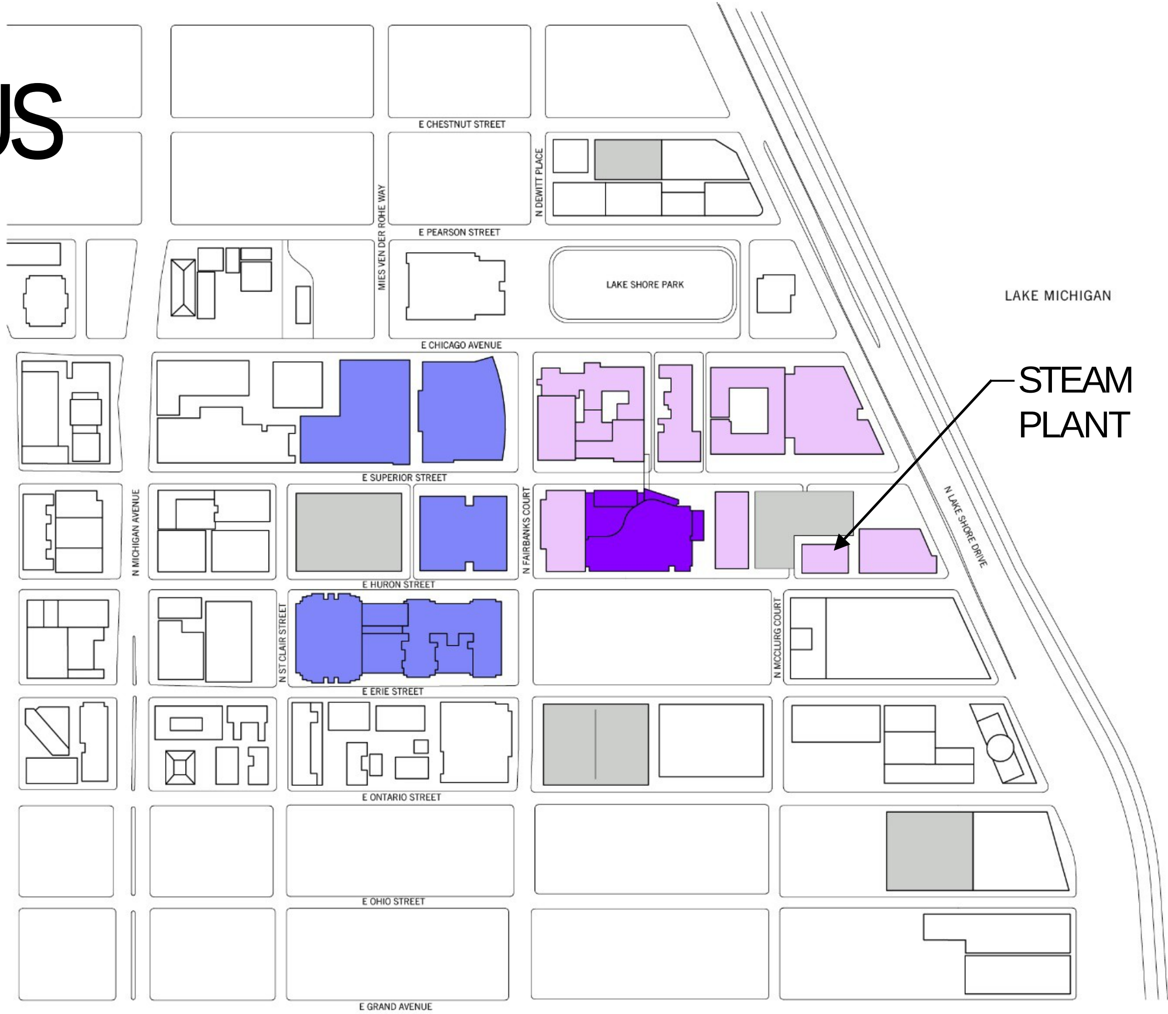
- Obsolete equipment
- Poor operating efficiency
- Significant overcapacity
- Crumbling distribution
- Northwestern Memorial Hospital Redevelopment

NWMH SHIFT FROM HPS

- NWMH Campus Fully Utilize HPS Plant — **1958**
- NWMH Feinberg / Galter Pavilion Construct with New Boilers — **1999**
- NWMH Lurie Children's Research Center New Construction — **2003**
- NWMH Prentice Women's Hospital New Construction — **2012**

CHICAGO CAMPUS

Steam Service Area

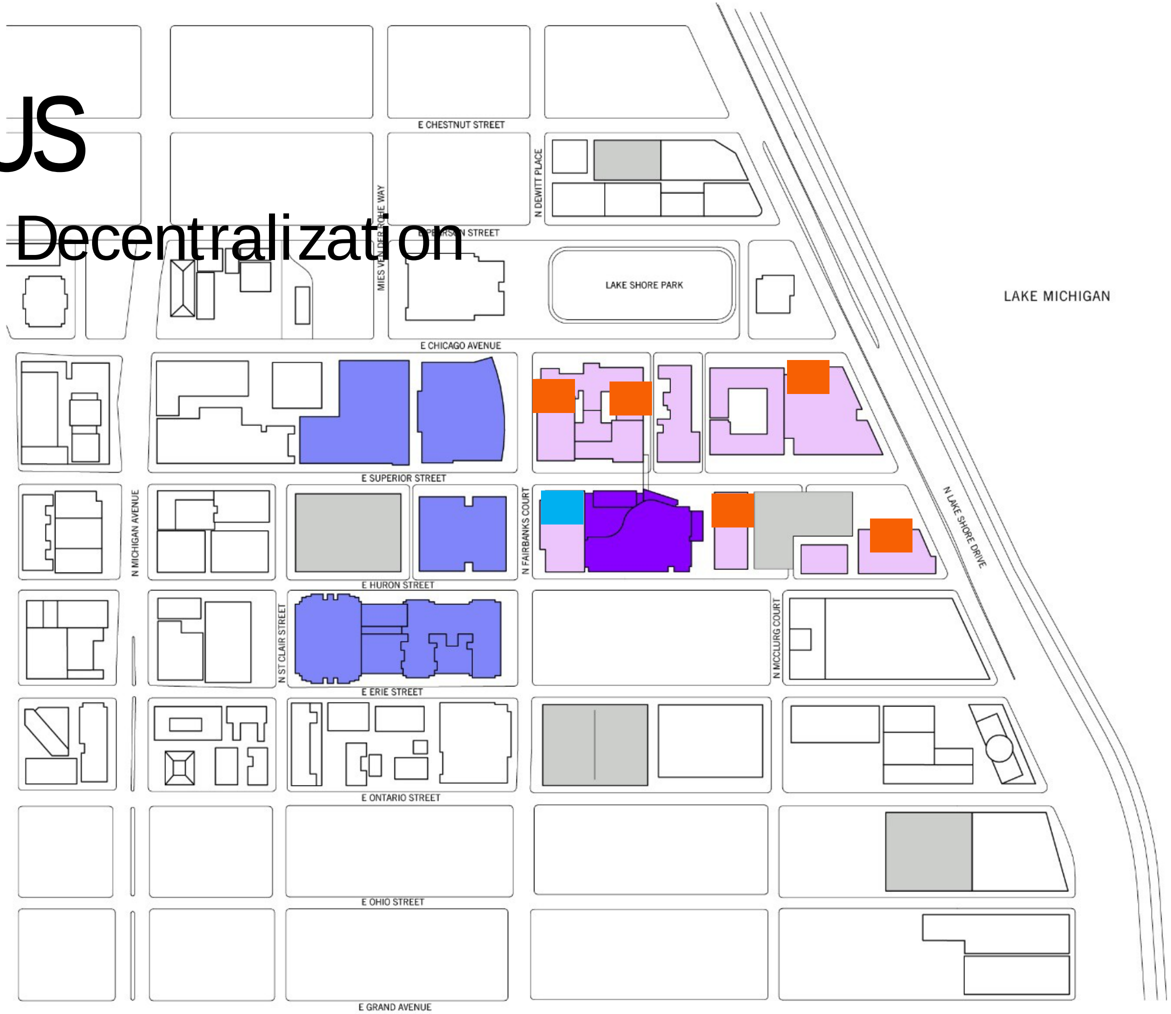


PROPOSED SOLUTIONS

- Capital renewal - Steam plant + distribution
- Conversion to co-generation
- **Decentralization to six satellite plants**
  - **Low pressure steam**
  - **Hot water**
  - **High pressure process steam**
- **Elimination of high pressure steam production**

CHICAGO CAMPUS

Proposed Steam Plant Decentralization



Satellite Hot Water / Steam Production Plants

- HW / LPS
- HW / LPS / HPS

HIGH PRESSURE STEAM

- Steam energy losses
  - Boiler blow down
  - Deaerator venting
  - Pressure reduction
- Maintenance
- Skilled boiler operators
- Continuous staffing

SQBRC MOVES AWAY FROM HIGH PRESSURE STEAM

SOLUTIONS FOR NU SQBRC

No Steam at SQBRC

- Dry Heat Sterilization
- Vivarium Cage Washer Alternative
- Atomizing Humidification
- Hot Water Boiler System

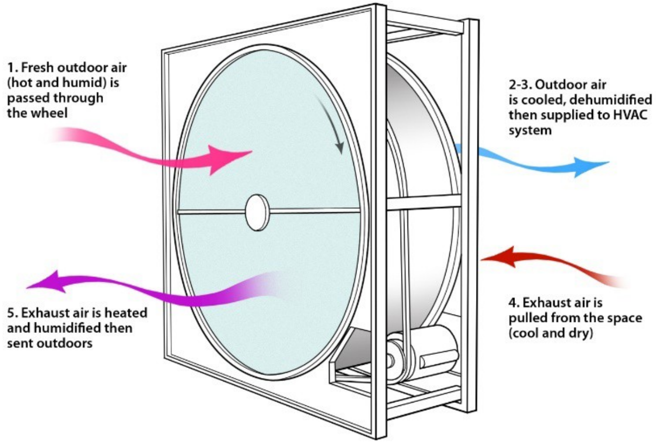
Low Pressure Steam at Lurie

- Low Pressure Steam Boilers in Lurie

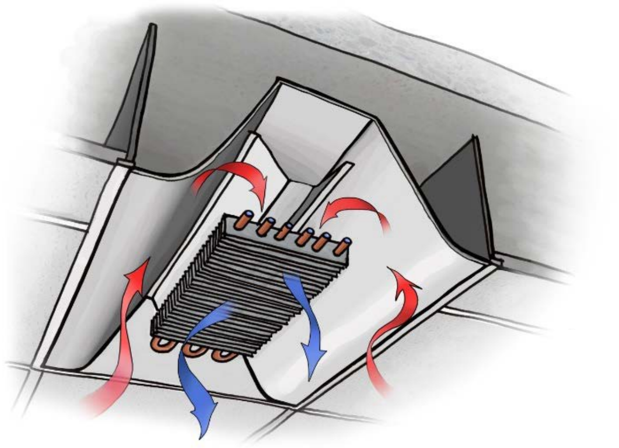
NU SQBRC LABORATORY EQUIPMENT

STEAM VS. DRY HEAT

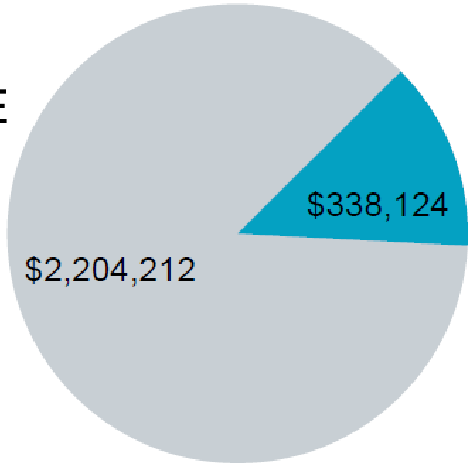
LIFE CYCLE COST ANALYSIS



- Options developed early
- Menu of nearly 100 alternatives evaluated
- Implementation costs + maintenance costs
- Full energy modeling
- Simple payback criteria – 7 years
- Options selected



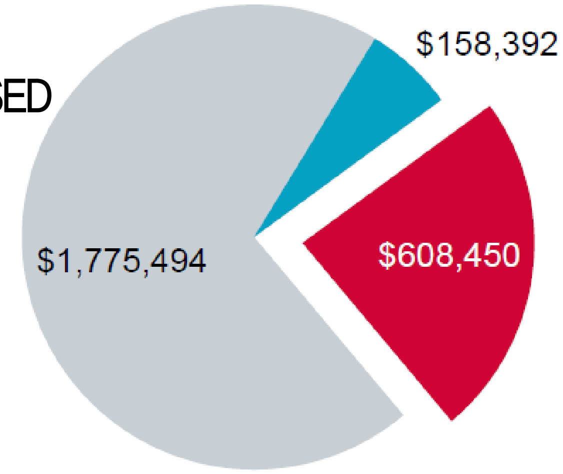
BASELINE



Electricity Savings	19%
Natural Gas Savings	53%
Annual Energy Savings	$608,450
Incentive	$463,244

All energy savings calculations contained in this report are estimates

PROPOSED



Electricity Gas Savings

MAJOR SUSTAINABLE FEATURES

- High efficiency façade
- Double skin – south façade
- Chilled beams
- High efficiency plants
  - o Condensing hot water boilers
    - o Low pressure steam
  - o Chilled water production
- Exhaust air heat recovery
    - o Non-fume exhaust / heat wheel
  - o Fume exhaust / run around
- Aircuity demand control
- Ultra low-temperature freezers
- Dry heat sterilization
- Atomizing humidification

Energy Efficiency Measures (see page 3 for detailed descriptions)		Energy Savings[1]		Peak Cooling Load	Incentives[2]
		$/yr	%	% Saved	$
1	Improve Envelope	$3,880	0.2%	0.1%	$1,646
2	Curtainwall Properties	$107,614	4.2%	4.2%	$88,189
3	Exterior Shading	$26,185	1.0%	1.1%	$29,519
4	Interior Lighting Power	$32,639	1.3%	1.2%	$36,935
5	Exterior Lighting Power	$160	0.0%	0.0%	$159
6	Chilled Beams	$171,375	6.7%	33.6%	$153,351
7	Condensing Boilers	$46,561	1.8%	0.0%	$4,284
8	Condensing DHW Heater	$2,134	0.1%	0.0%	$0
9	Chiller Cooling Efficiency	$84,677	3.3%	0.0%	$84,677
10	Demand Control Ventilation	$39,824	1.6%	0.5%	$19,150
11	Supply Air Temperature Reset	$10,242	0.4%	-0.4%	$3,265
12	Energy Recovery Ventilation	$12,987	0.5%	0.5%	$8,971
13	Heat Rejection Plant	$23,982	0.9%	0.0%	$23,981
14	Regenerative Elevators	$9,117	0.4%	0.0%	$9,117
15	Heat Recovery Chiller	$37,073	1.5%	0.0%	$0
Totals (1-15)		**$608,450**	**23.9%**	**40.8%**	**$463,244**

[1] Annual energy cost savings based on $0.10/kWh and $0.70/therm.

[2] Incentives are preliminary until approved by the utility. Approval will occur following receipt of the signed Measure Incentive Agreement.

ECM M-4:

Ultra Low Temperature Engine Freezers

WHAT? Ultra low temperature (ULT) stirling engine freezers used in the linear equipment rooms (LERs) instead of conventional freezers. Fan coil units (FCUs) are implemented in the spaces to remove the high sensible load.

WHY? The sensible energy gain to the LER space from the ULT stirling engine freezer is relatively low, so the energy savings is both direct and indirect.

RESULTS? The stirling engine freezers reduce a significant amount of the building's annual electricity. The lower equipment power density (EPD) allows the minimum air change rate while the fan coil unit removes the remaining sensible load. This ECM may be eligible for a LEED Innovation in Design credit.

ASSUMPTIONS

The energy model implemented the reduced EPD for all of the LER spaces and the freezer farm in the building.

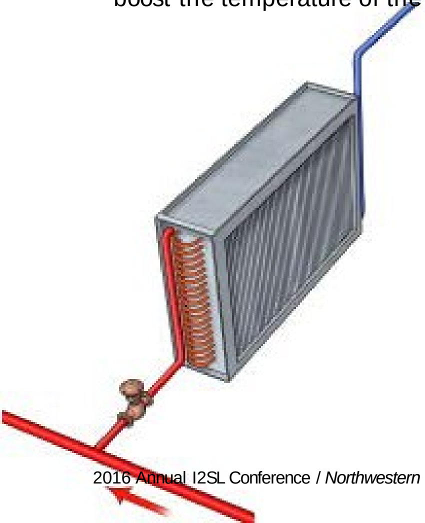
Decision Component	Value	delta vs Baseline
Capital Costs	$444,000	$(444,000)
Electricity Costs	$1,942,500	$175,900
Gas Costs	$355,800	$4,600
Total Energy Costs	$2,298,300	$180,500
Rebates & Incentives	$146,200	$146,200
Annual Maintenance	$ -	$ -
Replacements (over 40 yrs)	$ -	$ -
Electricity Consumption	27,845,500	2,521,700
Natural Gas Consumption	711,600	9,100
Net LCC	$76,701,600	$5,565,300
Discounted Payback	1.66	
NPV	$5,565,300	

Modeling Assumptions:		Proposed	Base
Total Area:	sf	19,200	NA
LER modeled EPD	W/sf	14	22

ECM M-1A:

Combined Preheat Run-around Loop Heat Recovery for Labs

WHAT? A combined run-around loop (CRAL) functions like other run-around loops such that it transfers air from the exhaust air and transfers air to the incoming fresh air stream (in some control operations). However, this CRAL also incorporates a heat exchanger to boost the temperature of the incoming air to the desired set point.



WHY? The CRAL can eliminate the need for a reheat or preheat coil and save fan energy.

RESULTS? The combined runaround energy recovery does indeed reduce the amount of natural gas consumption at the building air handler saves some fan power compared to the other heat recovery devices.

ASSUMPTIONS
The energy model implemented the CRALs in the air handlers of the laboratories.

Decision Component	Value	delta vs Baseline
Capital Costs	$(421,700)	$421,700
Electricity Costs	$1,949,400	$(13,500)
Gas Costs	$356,200	$81,100
Total Energy Costs	$2,305,600	$67,600
Rebates & Incentives	$316,600	$316,600
Annual Maintenance	$4,800	$(4,800)
Replacements (over 40 yrs)	$36,000	$(36,000)
Electricity Consumption	27,944,400	2,422,800
Natural Gas Consumption	712,400	162,200
Net LCC	$76,059,100	$3,250,300
Discounted Payback	0.00	
NPV	$3,250,300	

Modeling Assumptions:		Proposed	Base
AHU Supply Fan Power:	kW/CFM	0.00125	0.0012
AHU Exhaust Fan Power:	kW/CFM	0.0009	0.0008
RAL Sensible Effectiveness		0.4	0
RAL Latent Effectiveness		0	0

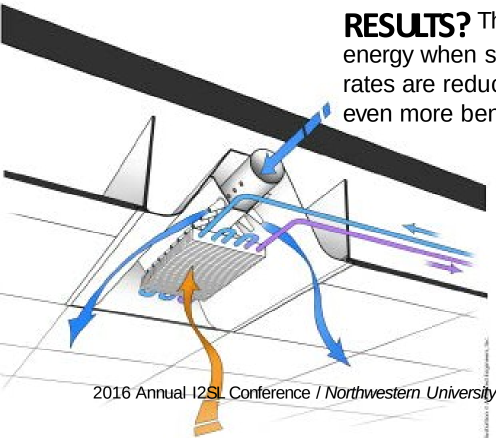
ECM M-5C:

Active Chilled Beams in Labs & Offices

WHAT? An active chilled beam (ACB) is a terminal device that not only provides the minimum airflow to the space, but it also conditions the space air via an induction process. The induction process brings the space air over coils in the chilled beam with either the process chilled water loop or the heating hot water loop.

WHY? Spaces with ACBs can maintain the minimum airflow while the coils can meet the sensible load demands thus saving on energy by not bringing more expensive-to-condition OA than necessary to meet the sensible loads.

RESULTS? The use of ACBs can contribute significantly to reducing energy when sensible loads in labs mature. If the minimum air change rates are reduced even more with air monitoring, the ACBs will contribute even more beneficially.



ASSUMPTIONS

The energy model implemented the ACBs in the labs, lab support, LERs, and offices. For this analysis, loads peaked at 50% of design load with many hours being less than that. This is in alignment with Labs21 equipment utilization schedules/patterns as well as AEI equipment load monitoring.

Decision Component	Value	delta vs Baseline
Capital Costs	$381,400	$(381,400)
Electricity Costs	$1,836,900	$99,000
Gas Costs	$388,300	$49,000
Total Energy Costs	$2,225,200	$148,000
Rebates & Incentives	$98,000	$98,000
Annual Maintenance	$ (153,200)	$153,200
Replacements (over 40 yrs)	$ -	$ -
Electricity Consumption	26,331,700	4,035,500
Natural Gas Consumption	776,600	98,000
Net LCC	$70,312,700	$8,996,700
Discounted Payback	0.00	
NPV	$8,996,700	

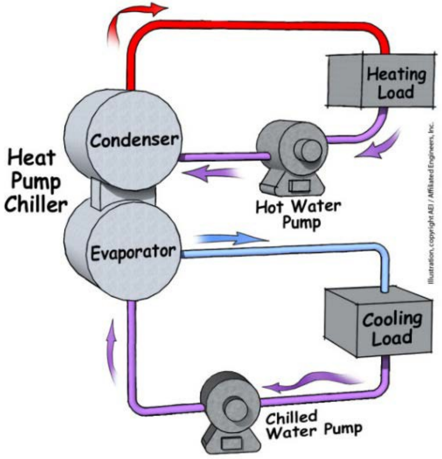
Modeling Assumptions:		Proposed	Base
AHU Supply Fan Power:	kW/CFM	0.00105	0.0012
AHU Exhaust Fan Power:	kW/CFM	0.0008	0.0008
Induction Ratio		4.0	NA

ECM M-3:

Heat Recovery Chiller

WHAT? Heat recovery chillers can simultaneously heat the heating hot water (HHW) loop and process chilled water (CHW) loop. Thus, when there is a need for both heating and process chilled water, this device can operate to simultaneously meet both of the loads.

WHY? In laboratory buildings in a northern climate, there are often times when there is a demand for both heating (at the air handler and perimeter zones) and process cooling. This device also reduces cooling tower water consumption.



RESULTS? The heat recovery chiller is priced and specified for 400 tons. Partial installation might be considered, as the initial simulation runs with the chiller for the first year were less than the specified capacity. Nonetheless, as the building, equipment, and occupants mature, more capacity is necessary.

ASSUMPTIONS

The heat recovery chillers serve the process chilled water loop (PCHW) and the heating hot water loop. There were no active chilled beams in the model that would also provide more cooling load for the heat recovery chiller.

Decision Component	Value	delta vs Baseline
Capital Costs	$637,800	$(637,800)
Electricity Costs	$2,113,600	$4,800
Gas Costs	$331,400	$29,000
Total Energy Costs	$2,445,000	$33,800
Rebates & Incentives	$452,500	$452,500
Annual Maintenance	$7,100	$(7,100)
Replacements (over 40 yrs)	$366,000	$(366,000)
Electricity Consumption	30,298,200	69,000
Natural Gas Consumption	662,800	57,900
Net LCC	$81,626,000	$640,900
Discounted Payback	7.01	
NPV	$640,900	

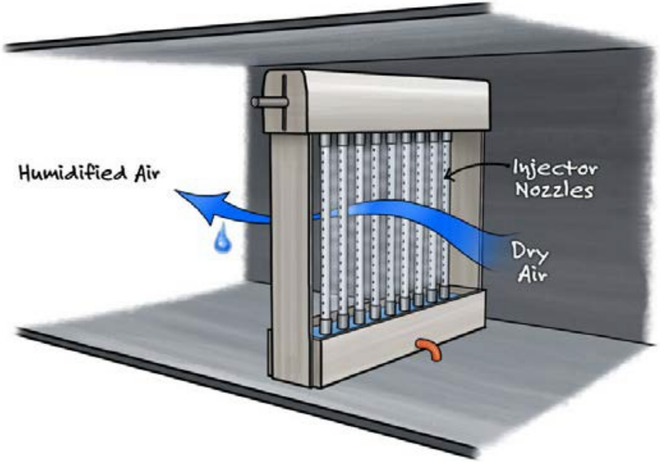
Modeling Assumptions:		Proposed	Base
Installed Capacity	tons	400	NA
Nominal EER	F	10.5	NA
HHW Design Temperature		130	NA
Process CHW Temperature	F	58	NA

ECM M-14:

Atomizing Humidification

WHAT? Atomizing humidification uses pumps to pressurize water and send the water through tiny injector nozzles in the AHU air stream. These systems intend to use revers osmosis (RO) water for the humidification.

WHY? Atomizing humidification eliminates the need for the low pressure steam system with the associated steam piping and natural gas. The AHU air stream temperature will remain virtually the same unlike with steam humidification.



RESULTS? Eliminating the steam system for humidification is not an insignificant amount of natural gas. With the unpredictability of the natural gas prices, this might continue to be a viable option.

Decision Component	Value	delta vs Baseline
Capital Costs	$(164,000)	$164,000
Electricity Costs	$2,118,400	$ -
Gas Costs	$342,100	$18,300
Total Energy Costs	$2,460,500	$18,300
Rebates & Incentives	$36,300	$36,300
Annual Maintenance	$(4,600)	$4,600
Replacements (over 40 yrs)	$318,000	$ (318,000)
Electricity Consumption	30,367,000	200
Natural Gas Consumption	684,200	36,500
Net LCC	$81,395,300	$871,600
Discounted Payback	0.00	
NPV	$871,600	

Modeling Assumptions:		Proposed	Base
LPS Boiler Eff		NA	0.85
Condensing Boiler Efficiency		0.93	NA

Questions / Discussion